DOCUMENT RESUME

ED 396 676 IR 017 852

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TITLE The CoVis Collaboratory Notebook: Supporting Collaborative Scientific Enquiry.
PUB DATE 94
NOTE 8p.; In: Recreating the Revolution. Proceedings of the Annual National Educational Computing Conference (15th, Boston, Massachusetts, June 13-15, 1994); see IR 017 841.
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Computer Mediated Communication; Computer Networks; *Computer Software Development; Courseware; Database Design; Educational Technology; *Hypermedia; *Inquiry; Journal Writing; *Science Activities; *Scientific Methodology; Secondary Education; *Student Projects; Visualization
IDENTIFIERS *Collaborative Learning; National Science Foundation

ABSTRACT

The Collaboratory Notebook is a networked hypermedia database that allows students to collaborate on scientific inquiries across boundaries of time and space. Developed as part of the Learning Through Collaborative Visualization (CoVis) networking testbed, sponsored by the National Science Foundation, this software expands on the idea of traditional science lab notetaking. The Notebook provides an introduction to the process of scientific inquiry for beginners. It allows students to record their own ideas privately or publicly, browse the recorded ideas of others, and participate in collaborative dialogue and visualization about those ideas. The Collaboratory Notebook has been used by teachers and students in five earth science classes at Evanston Township and New Trier High Schools in suburban Chicago. They are exploring its uses within the large CoVis community which includes over 300 students, teachers, educational researchers, and research scientists. (Author/BEW)

The CoVis Collaboratory Notebook: Supporting Collaborative Scientific Enquiry

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Key words: collaboration, distance learning, hypermedia, project science, scientific visualization

Abstract

The Collaboratory Notebook is a networked hypermedia database that allows students to collaborate on scientific inquiries across boundaries of time and space. Developed as part of the CoVis networking testbed, this software expands upon the traditional laboratory notebook. In the Notebook, users express their ideas, record their actions and respond to others in a medium that is structured specifically for the task of scientific inquiry.

Introduction: The CoVis Project

The Learning Through Collaborative Visualization (CoVis) Project is an NSF-sponsored networking testbed designed to explore the use of new computing and communications technologies in support of project-enhanced science learning. The goal of CoVis is to provide high school students with opportunities to learn about science by engaging in scientific inquiry themselves. In achieving this goal, the CoVis project focuses on three themes: *project-enhanced science learning*, *scientific visualization*, and *collaboration*.

Project-enhanced science learning (Ruopp, Gal et al. 1993) represents a transition from traditional textbook- and lecture-oriented classrooms to ones in which learning occurs in the course of scientific inquiry. In this approach to pedagogy, students play an active role in formulating research questions and pursue them in collaboration with their peers, teachers and scientist mentors. In the process of these investigations, students acquire a deeper understanding of the subject matter addressed, and learn other valuable lessons about how scientific inquiry is accomplished.

An important principle behind project-enhanced science learning is that the study of science should more closely resemble the practice of science by scientists. To make this possible, students must be able to conduct investigations similar to those of scientists, using similar tools. The second theme of the CoVis project, scientific visualization, is designed to place tools used by scientists in the hands of students. Scientific visulization plays an increasingly important role in many fields of science, including the atmospheric sciences. As a part of its overall effort, the CoVis project has adapted visualization tools used by scientists to be appropriate for use by high school students in earth and environmental science courses (Gordin, Polman and Pea, 1994; Fishman and D'Amico, 1994).

The third theme of the CoVis project is collaboration. Modern scientific workplaces are connected and collaborative in nature (Finholt and Sproull 1990; Lederberg and Uncapher 1989). In the atmospheric sciences particularly, researchers are making use of high-speed digital networks to support collaborations that span large distances (D'Amico, Fishman, Gordin, McGee, O'Neill and Polman, in preparation). To reflect this development in the high school learning environment, CoVis takes advantage of an advanced ISDN digital network to link its two participating high schools to Northwestern University, the University of Illinois at Urbana-Champaign, and the Exploratorium science museum in San Francisco. The goal of this network and the collaboration software that we provide is to allow students to work together with other students and to form informal mentoring relationships with professional scientists.

The Collaboratory Notebook

The Collaboratory Notebook is a networked application which has been designed to directly address the central goals of the CoVis project. Specifically, it is intended to:

- scaffold the inquiry process for students who have never performed independent inquiry before;
- integrate scientific visualization with other computer- and non-computer-based activities;
- provide a means for collaboration among participants who may be spread across institutions and across the country.

The design of the software reflects an attempt to address many of the challenges that project-enhanced science learning entails, both for students and teachers. Many of the students who make use of the software have never conducted independent research before, are unaccustomed to recording their thoughts and actions for future reference, and are unfamiliar with the structure of scientific arguments. The Collaboratory Notebook is an important part of the CoVis project's overall effort to encourage students to record and reflect upon the process of scientific inquiry, including false starts, missteps, and the redefinition of problems.

Teachers managing a project-centered science classroom must confront the general tendency in science education to product over process. By helping make more informal, intermediate products of students' work available to teachers and scientist mentors, the Collaboratory Notebook can serve as a technological lever to help teachers monitor student's learning processes. It can also encourage innovative assessment routines by eliminating the need for teachers to collect and grade their students' work *en masse* . Instead, a teacher can review electronic notebooks in an ongoing fashion that is more appropriate for guiding independent research.

The Structure of the Collaboratory Notebook

The Collaboratory Notebook is a medium for students to record their thoughts and actions as they perform scientific inquiry. Many of its facilities have been inspired by other communal databases for learning such as CSILE (Scardamalia and Bereiter 1991; Scardamalia, Bereiter et al. 1989), INQUIRE (Brunner 1990), and GroupWrite (Schank and Osgood 1993). However, the Collaboratory Notebook has many unique features of its own which arise from the large distributed community that it was created to support.

The Notebook's interface is built on the metaphor of a library; with bookshelves, notebooks ar pages being the primary interface elements. When a student or teacher logs on, a bookshelf displays all of the notebooks to which that individual has access (Figure 1),.

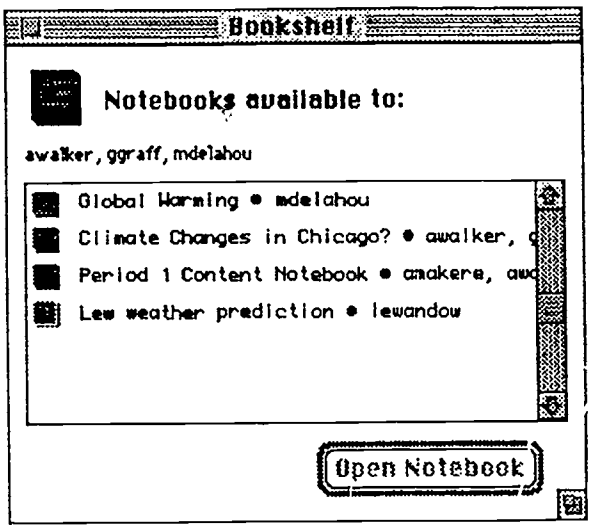

Figure 1. A Bookshelf. The color and letter on the icons at left indicate whether the notebook is a journal (J), project notebook (P) or discussion (D).

Notebook users can create three different types of notebooks. They are:

- **Private Journals.** A private journal can only be read or modified by its single owner.
- **Project notebooks.** A project notebook is shared by a group of individuals, all of whom may read or modify it. A project notebook provides a medium for a group of students, teachers and scientists to share inquiry.
- **Discussions.** A discussion is open to any member of a community. Discussion notebooks provide a medium for public dialogue among students, teachers, and scientists on a topic of mutual interest.

All of the notebook types share the same structure. A notebook consists of a title page with a brief description of the notebook's purpose, a table of contents, and any number of content pages. The table of contents for a notebook displays the notebook's title, a list of its authors, and an overview of its pages, including their types, titles and relational structure. The table of contents for a Project notebook is shown in Figure 2.

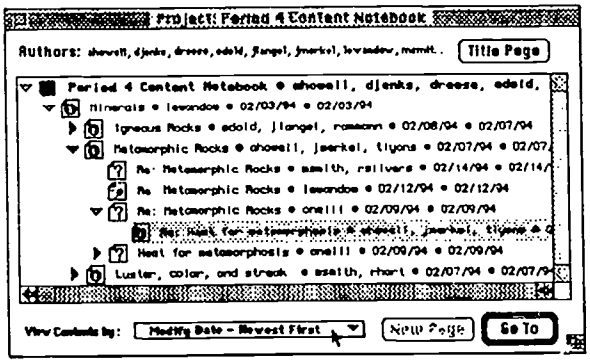

Figure 2. The table of contents for a whole-class project notebook.

Each page in a notebook has a type (indicated by its icon), a title, and a set of authors. Pages may be authored by individuals, or by a group of people working together at the same time. The types given to pages by their authors provide both a description of their contents, and of their relationship to other pages. The page types available to choose from in the current versio of the software are:

- **Information.** An information page can describe an experience, or offer some knowledge that is seen as useful to the investigation.
- **Commentary.** A commentary page offers a view on what has been written in another page, or suggests a direction for future investigation or discussion. Commentaries are useful for feedback and guidance from instructors.
- **Question.** A question page can be used to record one or many questions. These could include a response to the contents of another page or central research questions.
- **Conjecture.** A conjecture page is used to record hypothesized answers to questions in a notebook.
- **Evidence for.** An evidence-for page is used to provide justification for a conjecture. Evidence might take the form of scientific visualizations, information gathered from outside sources, or logical arguments.
- **Evidence against.** An evidence-against page contains evidence that contradicts a conjecture.
- **Plan.** A plan page records a plan for answering a question or verifying a conjecture.
- **Step in plan.** A step in plan is a page for recording the process and results of carrying out one step in a plan.

Notebooks are created by linking pages together in accordance with the structure of an inquiry.

Browsing and Authoring Pages in a Notebook

Because the Collaboratory Notebook is used for both reading and writing in the course of an investigation, it has been designed to support both activities equally well. Figure 3 shows a notebook page as it appears when it is being read.

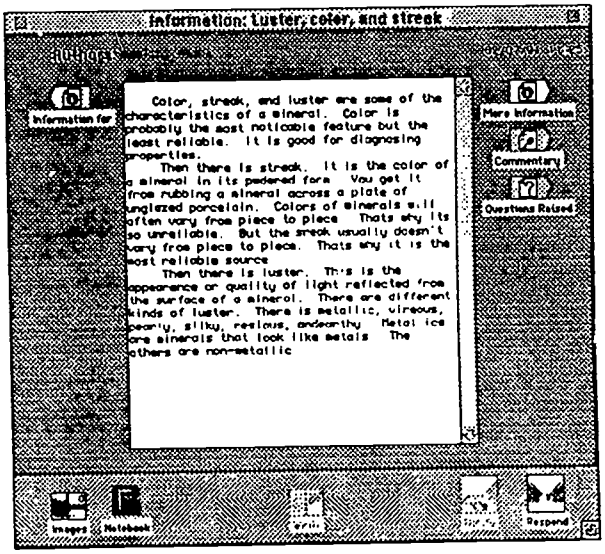

Figure 3. A question page from a project notebook.

The top of a notebook browsing window displays its title, its authors' names, and the dates it was created and last modified. On the right and left sides of the window are arrow-shaped buttons representing links that connect the page to others. On the left is an icon representing links *to* the displayed page from other pages that inspired it, and on the right are icons representing links *from* the displayed page to other responses. In other words, the Collaboratory Notebook maintains the convention that links between pages come from the left and go to the right.

When a user clicks on one of the arrow buttons with the mouse, she is presented with a list of pages of one particular type that are linked to the current page. For instance, if the user clicks the "questions raised" button, she sees a window displaying a list of pages containing questions in response to the page she is reading. She can then select any one of these questions to view, or can respond with a new question of his own.

To inform a reader, the background color of each arrow button changes to indicate how many pages of that type are linked to the current one. For example, if a question page has no conjectures attached to it, the background of the conjectures icon will be white. Once a user attaches a conjecture to this page, the background of the conjectures icon will change to a light shade of yellow. As more conjectures are added, the color changes to increasingly dark shades.

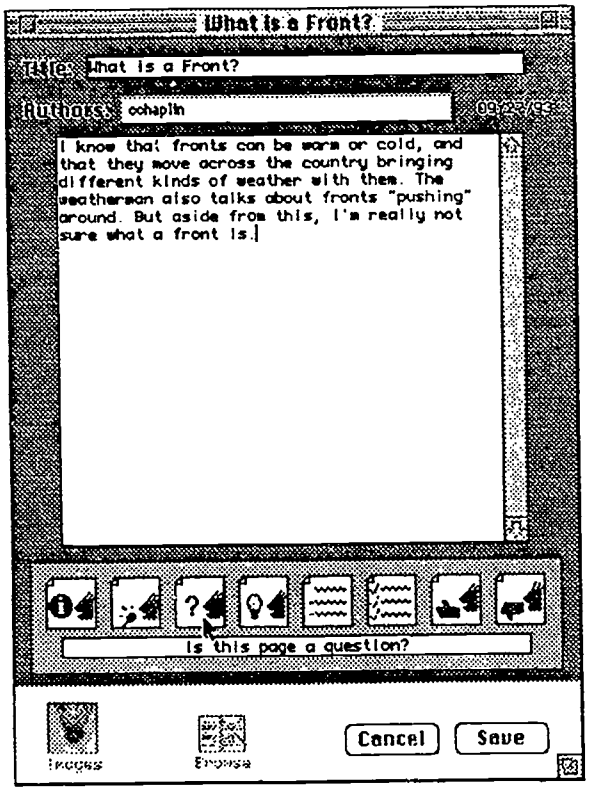

Figure 4. A question page being edited. The user classifies the page by clicking one of the icons in the lower section of the window.

When a page is being created or modified, it appears in a different form (Figure 4). The band of icon buttons near the bottom of the page writing window provides authors with options for classifying the page they are working on. This classification may be changed repeatedly as the authors' sense of what they have written and its place in the inquiry evolves; however the software requires that the user select a type for each page before saving it.

A Supporting Structure for Collaborative Inquiry

The particular outgoing link types that a page may have are determined by the type of that page, according to a process model of inquiry. To give an example of how this model applies, a Conjecture page may take Evidence-for and Evidence-against pages as responses, but a page that describes a Plan for an investigation may not. All page types haveoutgoing links for questions raised, more information, and commentary. These are known as *universal links*.

Page Type	Response Palette
Question	Information, Question, Commentary, Conjecture, Plan

Conjecture	Information, Question, Commentary, Plans, Evidence For, Evidence Against
Plan	Information, Question, Commentary, Step in a Plan

Figure 5. Response palettes available for Questions, Conjecture and Plan pages.

The page types and response palettes supported in the notebook have been chosen to help students give structure to inquiry by focusing on small, but necessary intermediate products. Employing a small, fixed set of page and link types offers two significant advantages. First, it provides students with a framework for conducting dialogue which is tailored to the task at hand. Second, it helps to encourage consistent conventions of use across the larger community which CoVis supports.

The structure of the notebook helps students to structure their inquiry through its interface. When a student has created a notebook entry from scratch, the Notebook prompts her to characterize it. Is it a question, a comment, information, a conjecture, or a plan? When a student reads a page, the interface reminds her of ways that she might choose respond to it. For example, if she's reading a conjecture, the display of that conjecture reminds her that in addition to raising questions, commenting, or adding information, she might respond by providing evidence for or against it. Similarly, when she's reading a question, she is reminded that she could propose a conjecture about that question or a plan to research an answer. Table 1 shows the response palette available from three types of notebook pages.

The utility of this scheme is that by creating a number of pages, each containing only a small amount of writing, a student can create a large, complex investigation in a stepwise fashion that makes the relations of the individual parts explicit. The collaborative nature of the work supported by the notebook means that participants can reflect directly upon each part, encouraging the authors to clarify or extend their contributions.

A second reason for using a small, fixed set of page and link types is that they lead to helpful conventions of use for the tool. These conventions will enable our large community of users to develop expectations about the contributions of others. In the few months in which the Collaboratory Notebook has been in use, we have already seen sets of conventions arise for the revision of successive drafts of students' project proposals, the organization of knowledge gained by students from interviews with experts, and the sharing of responsibility between teachers and graduate students for mentoring groups of students. Within these conventions, the small number of page types makes the selection of an appropriate type for a page nearly automatic; and the fact that the set of types is fixed allows students, teachers and scientists to develop expectations that are useful in reading the work of others. If students were free to create their own page and link types, one student reading another's work would not be able to form reliable expectations about the semantics of any particular link or page type.

Integration of the Notebook with Scientific Visualization

Scientific visualization tools are an important element of the CoVis software suite. To assist students in recording their inquiry and sharing in the inquiry of others, the Collaboratory Notebook is tightly integrated with these visualization tools. Each of the tools generates an automatic log of users' actions. Using standard Macintosh cut and paste operations, students can place sections of these activity logs into appropriate pages in their notebooks and elaborate upon these terse computer-generated logs with more extensive descriptions of the context in which those actions were taken, their purpose and results. In addition, students may attach images created by the visualization software or a painting program to any notebook page. These images can be titled and annotated to reflect their role in an investigation.

Collaboration Using the Notebook

The Collaboratory Notebook has been designed to support both synchronous and asynchronous collaboration. Shared project notebooks and discussions allow for participants anywhere on the Internet to contribute to an inquiry. Authors can be added to and removed from a notebook at any time to accommodate the dynamic nature of collaborative project groups. Within the classroom, several individuals can be logged into the notebook at a time, so that students can work together simultaneously at one computer. Any pages that are created in a multi-user session bear the names of all the users as authors. Also, since the CoVis software environment allows two users at separate computers to share one screen[1], authors at different locations can work as if they were sitting at the same keyboard, regardless of the distance that separates them.

[1] Screen-sharing in the CoVis environment is supported by Timbuktu and Timbuktu Pro from Farallon Computing.

Use of the Collaboratory Notebook

At the time of this writing, the Collaboratory Notebook has been used by teachers and students in 5 Earth Science classes at Evanston Township and New Trier High Schools in suburban Chicago. Together with the CoVis team, these teachers are continuing to explore its uses within the large CoVis community, which includes over 300 students, teachers, educational researchers, and research scientists. An analysis of some of the uses made of this tool, and lessons learned from them, are presented elsewhere (O'Neill and Gomez, 1994).

Acknowledgments

The authors would like to thank all of the CoVis team members and teachers for the contributions they have made to this research at every stage. In particular, we would like to thank Myrland J. Gray, the Collaboratory Notebook's lead programmer.

This research is supported by The National Science Foundation under grant #MDR9253462. The CoVis project has also received significant support from Ameritech, Bellcore, Apple Computer, Sun Microsystems, Aldus, and Farallon Computing.

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